A SEALING DEVICE FOR TEMPORARILY CLOSING A WELL OR A PIPE

The present invention relates to a sealing device for temporarily closing a well, in particular an oil well, or a pipe.

Such a device is well known in the technical field of drilling and operating oil deposits and is commonly referred to as a "packer".

It serves to separate two contiguous portions of a well or a pipe from each other temporarily, for example in order to perform investigations or repairs in one of said portions.

The invention relates more particularly to such a sealing device that is in the form of an inflatable balloon carried by a support for inserting in the well or the pipe, the balloon comprising an inflatable tubular membrane of circular section with a wall that is leakproof, flexible and elastic, and deformable radially outwards under the action of the pressure of an internal fluid so as to bear hermetically against the wall of the well or the pipe.

At rest, the diameter of the device and of the membrane is less than the diameter of the well or the pipe.

Once the device has been positioned in the desired zone, the membrane is generally inflated by pumping in a liquid, in particular water, a hydrocarbon, and/or the mud present inside the well or the pipe.

The fluid is raised to a high pressure, suitable for causing the membrane to expand and for pressing it firmly against the wall of the zone in question so as to close it hermetically in temporary manner.

Once the investigation and/or repair operations have been completed, the membrane is deflated and the device is withdrawn.

Naturally, it can be used again on a subsequent occasion for closing a new zone of the same well or the same pipe, or it can be transferred to another site into a new well or a new pipe in order to

perform the same function.

As an indication, in an oil field application, the membrane is generally about 1 meter (m) to 4 m long, with an initial outside diameter (i.e. when the membrane is not inflated) lying in the range about 70 millimeters (mm) to 150 mm, and with a wall thickness (when the membrane is not inflated) lying in the range about 15 mm to 25 mm.

The material from which the membrane is made is generally natural or synthetic rubber.

Appropriate installation of the membrane requires a relatively high internal pressure to be used, with a value, still by way of indication, that is usually about 30 mega pascals (MPa) to 40 MPa.

During inflation, the wall of the membrane is thus exposed to very large forces, which run the risk of damaging it, or even of causing it to explode.

That is why the membrane is generally reinforced, mechanically.

In conventional manner, such reinforcement is provided by at least one sheet of flexible strands, e.g. steel wires, embedded in the thickness of its wall, said sheet occupying a circularly cylindrical surface on the same axis as said membrane.

In a known embodiment, a pair of concentric reinforcing sheets are provided, each made up of a series of parallel flexible wires (or cables), e.g. made of steel, wound helically at a long pitch (i.e. at a small angle of inclination relative to the longitudinal axis of the device), the wires in the two layers having angles of inclination of similar size but of opposite directions.

In a non-inflated membrane, this angle is initially about 15°, for example; as the membrane is inflated the angle increases and reaches a final value of about 35° to 40°. In elaborate devices, at least one similar, third sheet (an auxiliary sheet) is provided disposed coaxially inside the other two sheets and made of wires that are finer and closer together than the wires of the outer (main) sheets.

The function of the auxiliary sheet is to oppose a phenomenon known as "extrusion" which is associated with the material constituting the wall of the membrane creeping outwards under the action of very high internal pressure, which runs the risk of forming a hernia passing through the gaps between certain reinforcing wires of the main sheets, and leading to the wall rupturing.

That technique is relatively satisfactory, but it does not completely eliminate the risk of material being extruded or the corresponding risk of the membrane being deteriorated.

The present invention seeks to resolve this problem by proposing a structure for the membrane that is suitable for eliminating or practically eliminating such a risk.

For this purpose, the sealing device of the invention includes at least one fiber layer, referred to as a "filter" layer, which is likewise circularly cylindrical in shape, and disposed concentrically, being embedded in the thickness of the wall of the membrane, inside relative to said sheet of flexible strands, said filter layer possessing a structure that acts as an anti- extrusion barrier, adapted to limit creep of the material constituting the wall of the membrane and to prevent it from passing outwards between the reinforcing strands under the effect of the pressure generated by the inflation fluid.

In a preferred embodiment, the device includes at least one pair of adjacent fiber layers, referred to as "filter" layers, which are likewise circularly cylindrical in shape, and are disposed concentrically one inside the other, being embedded in the thickness of the wall of the membrane, inside relative to said sheet of flexible strands, said pair of filter layers possessing a structure that acts as an anti-extrusion barrier, adapted to limit creep of the material constituting the wall of the membrane and to prevent it from passing outwards between the reinforcing strands under the effect of the pressure generated by the inflation fluid.

In addition, according to other advantageous and non-limiting characteristics of the invention:

- each of said filter layers is/are made up of a multitude of very fine fibers which extend parallel to one another forming a helix of very long pitch, in a direction that is inclined at a small angle relative to the axis of revolution of the membrane;
- the fibers constituting the two filter layers are inclined at the same acute angle relative to said axis of revolution of the membrane, but in opposite directions;
- the acute angle formed by the fibers relative to said axis of revolution lies in the range 5° to 15°;
- said fibers are made of a material having high traction strength, such as, in particular, fibers of aramid resin, carbon, or glass;
- said fibers are circular in section with a diameter lying in the range about 5 μm to 20 μm, and preferably in the range 10 μm to 12 μm;
- the packing density of said fibers in a cross- section plane is about 10,000 fibers per square millimeter (mm^2) ; and
- each of said filter layers possesses thickness of about 0.4 mm to 0,8 mm.

Other characteristics and advantages of the invention appear on reading the following description of a preferred embodiment of the invention.

The description is made with reference to the accompanying drawings, in which Figures 1 to 5 serve to illustrate an explanation relating to sealing devices of the same general type as those constituting the subject matter of the invention, Figure 6 to 10 show a membrane that is mechanically reinforced in accordance with the prior art; and Figures 11 to 14 show a membrane presenting the characteristics of the invention. In the drawings:

- Figure 1 is a highly diagrammatic axial section view of a sealing device positioned inside a well or a pipe in a zone that is to be closed, its membrane being still uninflated;
- Figure 2 is a view similar to Figure 1, after inflation;

- Figures 3 and 4 are cross-section views showing the membrane before and after inflation in section planes referenced respectively III-III and IV-IV in Figures 1 and 2 ;

- Figure 5 is a view analogous to Figure 2, showing a variant of the device,-

- Figures 6 and 7 are fragmentary cross-section views respectively before and after inflation of the reinforced wall of a prior art type of membrane fitted to a device of the kind shown in the preceding figures;

- Figures 8 and 9 are diagrams showing the angular positions of the reinforcing wires of said wall, respectively before and after inflation;

- Figure 10 is a view analogous to Figure 7 showing the phenomenon of material being extruded, i.e. the phenomenon which the invention seeks to overcome;

- Figures 11 and 12 are views analogous to Figures 6 and 7 respectively, showing the reinforced wall of a membrane fitted to a sealing device of the invention; and

- Figures 13 and 14 are diagrams showing the angular positions of the fibers in the filter layers, respectively before and after inflation of the membrane.

In Figure 1, reference T designates cylindrical casing lining the inside of a well or a pipe, of axis Z-Z'.

Although the axis is horizontal in the figure, said axis could naturally present any other orientation, in particular it could be oblique or vertical.

The sealing device 1 essentially comprises a support constituted by a pair of end washers 2a, 2b having a sleeve-shaped membrane 3 disposed between them, said membrane being circular in section.

The sleeve is made of a composite material comprising mechanical reinforcement embedded in a matrix of flexible and elastically deformable material, e.g. rubber. Its end portions are fixed in

leaktight manner to the washers 2a and 2b which close said ends.

Conventional means that are not shown serve firstly to move the device inside the tube T so as to be able to position it in register with the zone that is to be closed, and secondly to introduce a fluid, in particular a liquid, under high pressure to the inside of the tubular membrane 3 via a channel 20 that is pierced for this purpose through one of the washers (2a).

As shown in Figure 2, where the introduction of the liquid is symbolized by arrow F, the pressure P_i developed by the liquid has the effect of expanding the membrane radially outwards so that it presses firmly and intimately against the inside wall of the tube T. This provides the looked-for closure.

During this radial expansion, the membrane is observed to shorten, i.e. its two end washers 2a and 2b move towards each other, and simultaneously the thickness of the membrane becomes smaller.

Its initial diameter D_0 (see Figure 3) increases and its diameter D after inflation is about $1.5 \times D_0$ to about $2 \times D_0$.

In the variant of Figure 5, the device also includes a central tubular mandrel 4 which carries the end washers 40a, 40b between which the membrane 3 is mounted. The inflation fluid is introduced into the mandrel and penetrates into the inside of the membrane via radial holes 41 formed through the wall of the mandrel. The end washers 40a and 40b are mounted to slide in leaktight manner on the mandrel so as to adapt to the axial shortening of the membrane while it is being inflated.

As shown in Figure 6, the wall 30 of the membrane 3 is reinforced.

It has three sheets of flexible wires 5, 6, and 7 embedded in thickness of its wall.

Each of these sheets occupies a circularly cylindrical surface on the same axis as the membrane 3, i.e. on the axis Z-Z',

By way of example, the wires 5, 6, 7 are steel wires of circular

section.

The inner sheet is made of wires 5 of diameter that is considerably smaller than the diameter of the wires 6 constituting the middle sheet and the wires 7 constituting the outer sheet.

As an indication, the diameter of the wires 5 is about 0.5 mm, and the diameter of the wires 6 and 7 is about 3 mm.

In each of the reinforcing layers, the wires making up the layer are disposed parallel beside one another and practically in contact with one another, and they are wound helically around the longitudinal axis Z-Z' at a long pitch, i.e. at a small angle of inclination relative to said axis.

This angle, which is referenced α_0 in Figure 6, initially has a value of about 15° for example (i.e. when the membrane is not inflated); during inflation of the membrane this angle increases and reaches a final value a (Figure 9) of about 35° to 40°.

As shown in Figures 8 and 9, the wires 6 and 7 are inclined at an angle of substantially the same size, but the wires are oriented in opposite directions.

The finer wires 5 of the inner layer are oriented in a manner similar to the wires 7 of the outer layer. From Figures 6 and 7, it can be seen that inflation causes the radius of curvature of the section of the membrane to increase and causes the thickness of the membrane to decrease, said thickness going from a value e_0 to a smaller value e.

As mentioned above, inflation also shortens the axial length of the membrane.

The inclined disposition of the reinforcing wires 5, 6, and 7 enables these wires to accompany the multidirectional deformation of the membrane wall in which they are embedded. These wires oppose uncontrolled deformation of the membrane and they absorb the very large forces generated by the internal pressure P_i. It can be seen that the spacing between adjacent wires within a given sheet also increases,

The inner sheet of wires 5 that are finer but that are disposed more densely serves essentially not to absorb the forces generated by inflation, but to oppose the above-mentioned extrusion phenomenon. However it does not always achieve this successfully.

This problem can be explained with reference to Figure 10.

The mass of rubber is subjected to an internal fluid pressure Pi that is very high, being about 40 MPa which acts against its inside wall 300.

In addition, it is often simultaneously exposed to high temperature, in particular in oil drilling applications, so the rubber tends to be softened.

For these reasons, it can happen that the material constituting a region of said inner wall begins to creep and is pushed outwards, thereby forming an indentation 301. This localized thrust on the material can initially cause two adjacent wires 5 to move apart, with this increased spacing propagating to the neighboring wires 5 and creating a breach through the first sheet in a zone 31 of the wall. Once the breach has formed, the material can continue to creep and this progresses rapidly outwards, pushing apart in similar manner the wires 6 and then the wires 7 of the other sheets.

This creep, which is similar to extrusion, and which is represented by arrow E in Figure 10, ends up by causing the wall to rupture and the membrane to burst.

The arrangement of the invention which is shown diagrammatically in Figures 11 to 14 enables this problem to be solved.

It can be seen that the reinforcement in the wall structure in the example shown is identical to that described above, comprising two sheets of wires 6 and 7.

However this disposition is not essential.

In accordance with the invention, the inner sheet of wires 5 has been replaced by a pair of adjacent fiber layers 8 and 9 which are referred to by convention as "filter" layers since their function is to

provide a filter barrier against the flow of material so as to prevent the above-explained extrusion phenomenon being initiated and then carried through.

These filter layers are likewise circularly cylindrical in shape, being disposed concentrically one inside the other and embedded in the wall 30 of the membrane 3, inside relative to the sheets of wires 6 and 7.

The filter layer 8 is disposed immediately inside the filter layer 9, which means that there is no wall- constituting material between them.

These layers are adjacent, and possibly stuck to each other via a bonding film.

References 30_i and 30_e designate the portions of the wall 30 which are respectively internal and external relative to the dual layer 8, 9.

The wires 6, 7 are embedded in the portion 30e, which portion is bonded around the filter layer 9. The portion 30_i without any reinforcement is bonded to the inside of the filter layer 8.

Each of the filter layers 8, 9 is made up of a multitude of very fine fibers 80 or 90 respectively, extending parallel to one another and forming a helix of very long pitch, extending in a direction that is inclined little relative to the axis of revolution Z-Z' of the membrane (see Figure 13).

The fibers 80 and 90 are inclined at the same acute angle or at similar angles, β_0 relative to said axis of revolution Z-Z' of the membrane 3, but in opposite directions.

This angle β_0 advantageously lies in the range 5° to 15°.

It is therefore considerably smaller than the angle α_0 of the wires 6 and 7.

These fibers are made of a material that is both very flexible and that presents high traction strength.

As a particularly suitable material, mention can be made of aramid fiber.

The fibers are preferably circular in section and of a diameter of about 10 micrometers (μm) to 12 μm. If the fibers are considered as seen in a cross-section plane, their packing density is about 10,000 fibers per mm2.

As an indication, each of the filter layers 8, 9 possesses a thickness of about 0.4 mm to 0.8 mm.

The fibers are long filaments grouped together in a plurality of flat bundles, forming very fine (very thin) strips or strings wound helically one on another or one beside another over the entire length of the membrane, so as to form each of the two filter layers.

Because of their full initial inclination β_0, the fibers remain slack after radial expansion of the perform which gives rise to an increase in the angle of inclination to an angle β (see Figure 14). They are not under tension, unlike the reinforcing wires 6 and 7.

If the appearance of the extrusion phenomenon that is to be combated is considered anew under these circumstances, the material constituting the wall portion 30_i which is exposed to the high pressure and possibly also to high temperature tends to creep outwards. However it comes against the fiber barrier constituted by the layer 8. Each fiber 80 absorbs a fraction of the thrust and transmits it to the adjacent fibers. Because of the high density of these fibers, in order to be able to pass, the flow of material is constrained to follow a zigzag path through the micro-interstices between the fibers. In addition, its pressure drops because of the force absorbed by the fibers. Migration of material is thus braked very considerably, or even prevented.

The second layer 9 backs up the first layer 8,

Given the inclined dispositions in opposite directions of these fibers, the radial forces exerted by the first layer 8 are distributed uniformly over the second layer 9 which absorbs them in turn.

Because of the crossed orientation of the fibers 80 and 90, there is no or practically no risk of the fibers becoming spaced apart from one another in an axial direction leaving room for a hernia to form.

The material is prevented from forming a breach therethrough.

The looked-for barrier or filter effect is thus indeed achieved. The outward thrust of material (from the portion 30_i to the portion 30_e) is thus controlled, spread out, and absorbed upstream by the pair of filter layers 8 and 9.

There is, a fortiori, no longer any risk of the reinforcing wires 6 and then 7 becoming spaced apart from one another in an axial direction so as to leave room for a hernia to form.

The wires 6, 7 are thus free to perform to the full their role of wires reinforcing the membrane. Although the embodiment of the device described above possesses a pair of filter layers, it would not go beyond the ambit of the invention to provide the device with a single filter layer, or with more than two filter layers.